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POLARIZATION OF Λ° PRODUCED BY NEUTRONS WITH AN ENERGY OF ~ 40 GeV ON CARBON NUCLEI

BIS-2 Collaboration: Berlin - Budapest - Dubna - Moscow - Prague - Sofia - Tbilisi - Varna

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A.N.Aleev, V.A.Arefiev, V.P.Balandin, V.K.Birulev, V.D.Cholakov, A.S.Chvyrov, T.S.Grigalashvili, B.N.Gus'kov, I.M.Ivanchenko, I.N.Kakurin, N.N.Karpenko, D.A.Kirillov, I.G.Kosarev, V.R.Krastev, N.A.Kuz'min, B.A.Kulakov, M.F.Likhachev, A.L.Lyubimov, A.N.Maksimov, A.N.Morozov, Nguen Mong Zao, A.E.Senner, L.V.Sil'vestrov, V.E.Simonov, L.A.Slepets, M.Smižanska, G.G.Sultanov, G.G.Takhtamyshev, P.T.Todorov, R.K.Trayanov
Joint Institute for Nuclear Research, Dubna

K.Hiller, H.Novak, A.V.Pose, H.-E.Ryseck
Institute of High Energy Physics, Academy of Science of GDR, Berlin-Zeuthen

A.S.Belousov, A.M.Fomenko, E.I.Malinovsky, S.V.Rusakov, Yu.V.Soloviev, P.N.Shareiko, L.N.Shtarkov, Ya.A.Vazdyk
Lebedev Institute of Physics, Academy of Sciences of USSR, Moscow

E.A.Chudakov
Institute of Nuclear Physics, Moscow State University, Moscow

E.D.Molodtsov
Institute for Nuclear Investigations, Academy of Sciences of USSR, Moscow

J.Hladky, S.Nemeček, M.Novak, A.Prokeš
Institute of Physics, Chekhoslovakian Academy of Sciences, Prague

V.J.Zayachky
Higher Chemical-Technological Institute, Sofia

D.T.Birulkov, V.I.Genchev, I.M.Geshkov, P.K.Markov
Institute of Nuclear Research and Nuclear Energetics, Bulgarian Academy of Science, Sofia

V.P.Dzhordzhadze, V.D.Kekelidze, N.L.Lomidze, G.I.Nikobadze, R.G.Shanidze
Institute of High Energy Physics, Tbilisi State University, Tbilisi

T.V.Gvakharia
Special Construct Bureau for Scientific Instrument, Academy of Sciences of Georgia, Tbilisi

The experiments [1-8] have shown that in inclusive processes Λ°, produced by >20 GeV protons on nucleons and nuclei, have a significant polarization which increases with increasing the transverse ($P_\perp$) momentum of Λ°-particles.

A qualitative explanation of this effect is given, e.g., in papers [3,9,10,11].

Close to unity, the polarization of Λ°, produced by ~7 GeV/c neutrons in a propane bubble chamber, is observed in the kinematically forbidden region of Λ° production on free nucleons [12].

In this paper we present new results on a measurement of the polarization of Λ°, produced by neutrons on carbon nuclei, based on the analysis of about 80000 Λ° decays.

First results of this experiment are presented in papers [13].

The polarization of Λ° was determined by measuring asymmetry in $\Lambda^\circ \to p + \pi^-$ decays relative to the plane of Λ° production. The contribution of Λ° from Σ° decays was not taken into account.

The experiment was carried out at the Serpukhov accelerator using the BIS-2 spectrometer [14] on-line with an EC-1040 computer. A layout of the spectrometer on the beam of channel 4N is shown in fig.1. The beam of neutrons at a mean energy [15] of (40 ± 5) GeV, preliminary cleaned from γ-quanta by a lead filter 10 cm thick and then from charged particles by an SP-129 magnet and a system of steel collimators, was incident on the target containing carbon nuclei.

The spectrometer comprises two-coordinate proportional chambers (PC) [16]. The spacing between the signal wires is 2 mm for all PC, PC5, PC7 and PC9 were rotated at the angle of $\pm 22.5°$ relative to the others. The signal X-electrodes of PCs have both individual outputs and outputs joined in hodoscope counters [17]. The logic of trigger requires the passage of four and more charged particles through the detectors (PC and H1). When charged particles pass through the spectrometric magnet SP-40, the transverse component of their momentum changes by 0.64 GeV/c.

Two samples of targets (T) were used in the experiment: a carbon plate 5 cm in diameter and 6.24 g/cm^2 in thickness and two 4x6 cm^2 scintillation counters 3 cm thick. To get rid of possible systematic errors in experimental results, the statistics was obtained with the vector of the magnetic field in the SP-40 magnet directed "up" and "down". Besides, the distance between the target and the centre of the SP-40 magnet was changed which led to changing the decay region for Λ° and the effective aper-

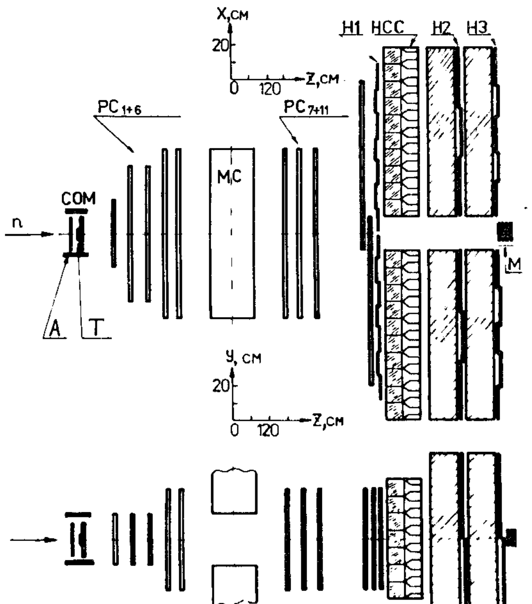


Fig.1. Layout of BIS-2 on channel 4N of the Serpukhov accelerator. H1 - scintillation hodoscope; PC(1÷11) - proportional chambers; HCC - hodoscope of the Cherenkov total absorption counters; H2, H3 - hodoscope of the muon detector; M - counters for monitoring neutrons; MC - magnet; T - target; A - anticounter.

ture of the spectrometer. The programs "Perun" /18/ and "View" were used for geometrical reconstruction of $1.2\cdot10^7$ primary events. In the further analysis of particle tracks and the selection of Λ° candidates it was required to fulfil the following conditions:

1. The distance between the extrapolation of two particle tracks to the median plane of the magnet is >10 cm.
2. The effective masses of two particles with equal signs of charge are >312 MeV/c^2 on the assumption that they are pions.
3. The angle between the tracks of particles having opposite signs of charge is >0.25 mrad.
4. The distance from the median plane of the SP-40 magnet to the decay point of Λ° candidates is >270 cm.
5. The distance from the target centre to the decay point of Λ° candidates is >12 cm.
6. The minimum distance between the tracks of particles from the decay of Λ° candidates is smaller than 0.3 cm.
7. Assuming that one particle is a proton and another is a pion, their effective masses are
   a) 1111 MeV/c^2 $<M(p\pi^-)<$ 1120 MeV/c^2 or
   b) 1105 MeV/c^2 $<M(p\pi^-)<$ 1109 MeV/c^2,
   c) 1123 MeV/c^2 $<M(p\pi^-)<$ 1127 MeV/c^2.

The tracks were assumed to be substantially different if conditions 1,2 or 3 were fulfilled. Otherwise of these tracks one was left with the best χ^2 per degree of freedom. If in one event there were several candidates of Λ°, one was left with a minimal value of χ^2.

The events, satisfying criterion 7b, were used to estimate and subtract background events.

Similar selection criteria were used for a part of the statistics to select $K^\circ_s\to\pi^+\pi^\mp$ candidates.

The effective mass, longitudinal and transverse momentum distributions of 83705 candidates of Λ° and 26055 candidates of K°_s are shown in figs.2 and 3, respectively.

The Λ° polarization was measured relative to the normal ($\bar{Y}$) to the plane of Λ° production. In this case Cartesian coordinates $\bar{X}, \bar{Y}=\bar{n}\times\bar{P}, \bar{Z}=\bar{P}$ were used, where $\bar{n}$ and $\bar{P}$ are unit vectors along the axis of the beam of neutrons and the momentum of Λ° in the laboratory system, respectively, and X was chosen so that the coordinate system was right.

If the polarization of Λ° is P, the density of the probability of the number of protons from decay $\Lambda^\circ\to p+\pi^-$ can be written as (see, e.g., /19/)

$$\frac{dW}{d\cos\Theta}\sim(1+\alpha\,\mathcal{P}\cos\Theta)/2, \qquad (1)$$

where $\alpha = 0.642$ /20/, the parameter of asymmetry in decays $\Lambda^\circ\to p+\pi^-$

$$\cos\Theta=\bar{Y}\cdot\bar{P}_p\,/\,|\bar{P}^*_p|. \qquad (2)$$

Here $\bar{P}^*_p$ and $\bar{P}_p$ are the proton momenta in the Λ° rest system and in the laboratory system, respectively.

The polarization of Λ° versus P was found from the experimental data using relations (1) and (2).

All candidates of Λ° were divided into groups of $P_\perp$ intervals. The first intervals of P were equal to 0.2 GeV/c, and the last one was opened from large $P_\perp$.

The $\cos\Theta$ distributions were constructed for each group of events both for the events, satisfying condition 7a, and for the background events satisfying 7b. After normalization the distributions of background events were subtracted from the corresponding distributions satisfying condition 7a.

Below for short we use the designations $X=\cos\Theta$ and $\beta=\alpha P$. The experimental distributions of events for each $P_\perp$ interval versus X can be presented as

$$N_E(X)=\frac{dW(X)}{dX}\,\Phi(X), \qquad (3)$$

where

$$\Phi(X)=\int N(U)\,\epsilon(U,X)\,dU, \qquad (4)$$

U is a six-dimensional variable characterizing the momentum and coordinates of the decay point of Λ° ; N(U) is the number of produced Λ° in the interval dU ; $\epsilon(U,X)$ is the efficiency of Λ° registration.

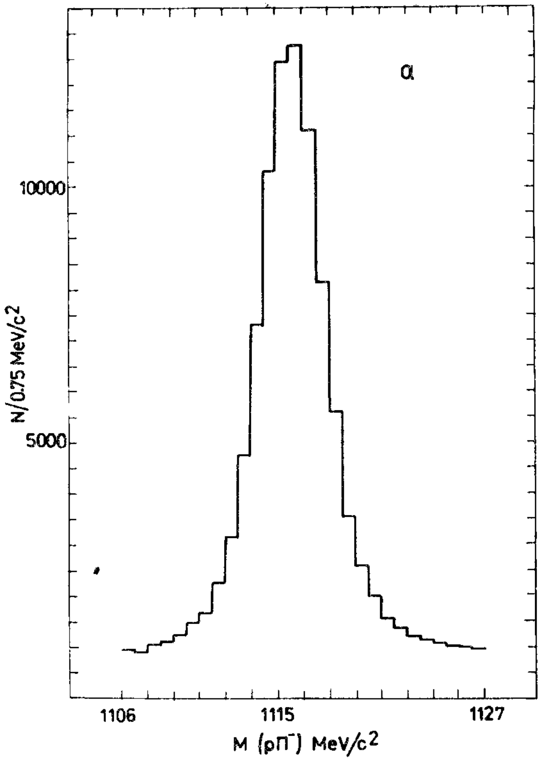
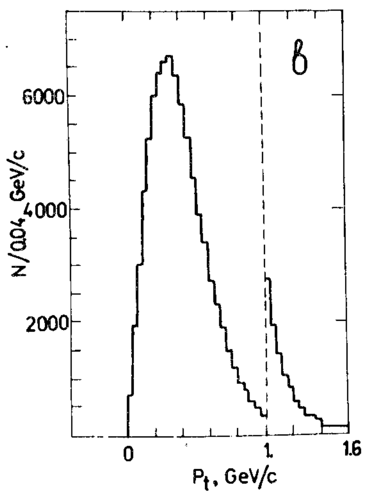


Fig.2. Distributions of events over: a) $M(p\pi^-)$ effective mass, b) Λ° transverse momentum, c) Λ° longitudinal momentum.



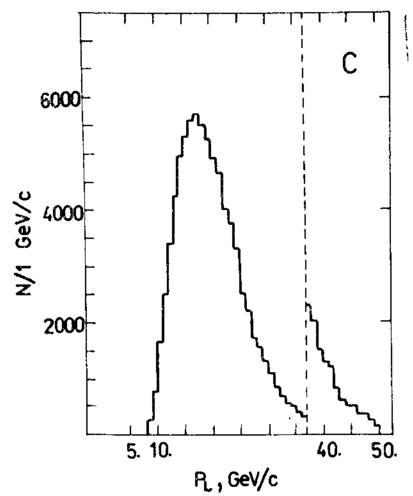
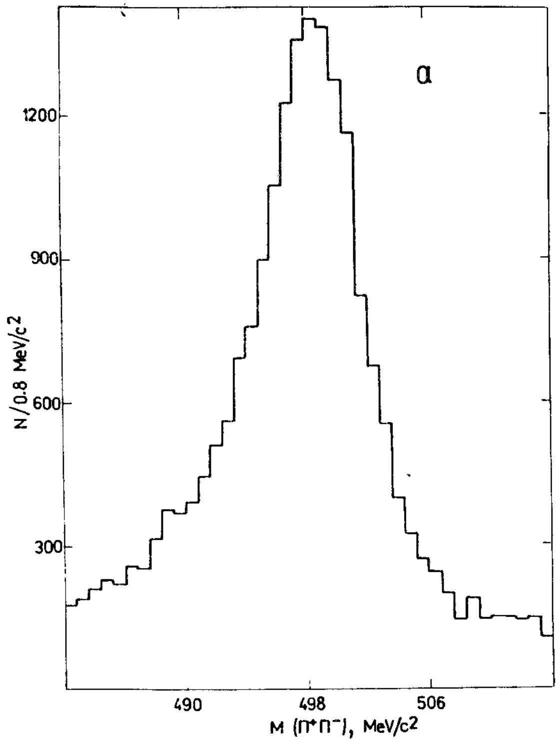
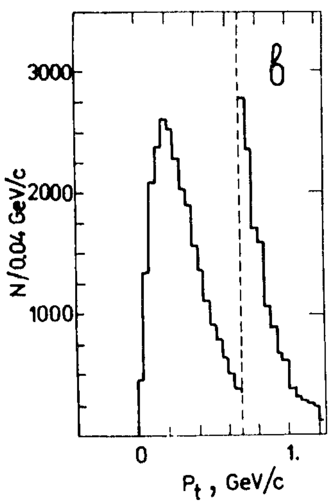
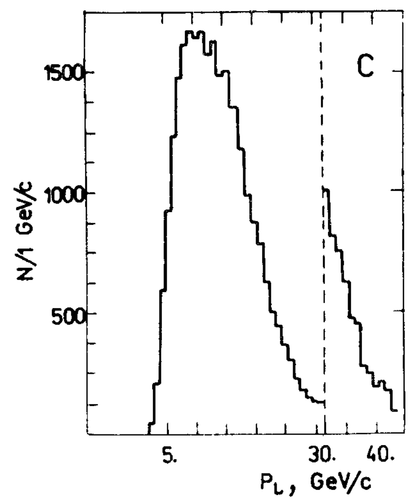


Fig.3. Distributions of events over: a) $M(\pi^+\pi^-)$ effective mass, b) K°_s transverse momentum, c) K°_s longitudinal momentum.







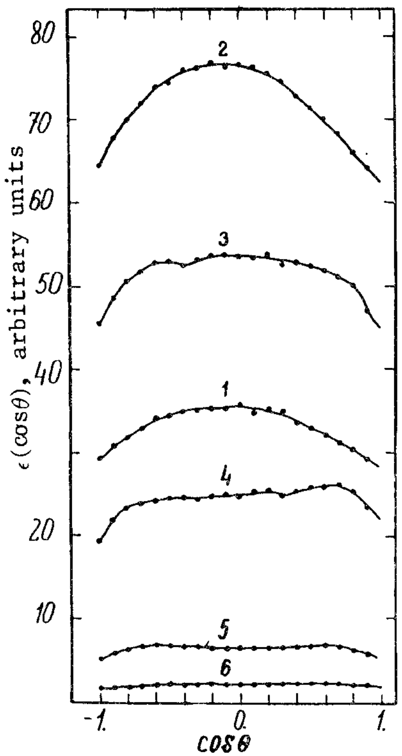


Fig.4. Detection efficiencies for six $P_\perp$ intervals in relative units. The $P_\perp$ intervals are denoted by figures: 1 - (0÷0.2) GeV/c; 2 - (0.2÷0.4) GeV/c; 3 - (0.4÷0.6)GeV/c; 4 - (0.6÷0.8) GeV/c; 5 - (0.8÷1)GeV/c; 6 - larger than 1.0 GeV/c.

From eq. (3) it follows that for the calculation of Λ° polarization it is sufficient to know the function $\Phi(X)$ that was determined by Monte-Carlo simulation. In simulation, the events detected in the experiment were used, the number of which in the interval ΔU is

$$\Delta N_E(U) = N(U)\,\Delta U \int_{-1}^{+1} \frac{dW(X)}{dX}\,\epsilon(U,X)\,dX . \qquad (5)$$

The isotropic decay of Λ° into proton and pion was assumed. The known experimental conditions, the logic of geometric reconstruction programs and the criteria of statistical data analysis were taken into account.

As a result, the distributions were obtained

$$N_n(X) = C \int N(U)\,\epsilon(U,X)\,(1+\beta\bar{X}(U))\bar{X}^n(U)\,dU , \qquad (6)$$

where $n = 0,1,2,3$; C is a constant, $\epsilon(U,X)$ is the efficiency of Λ° detection;

$$\bar{X}(U) = \int_{-1}^{+1} X\,\epsilon(U,X)\,dX \Big/ \int_{-1}^{+1}\epsilon(U,X)\,dX .$$

As is seen, for $n = 0$ the right-hand sides of eqs. (4) and (6) differ from one another by factor $(1+\beta\bar{X}(U))$ under the integral.

As $\beta\bar{X}(U) = \alpha\mathcal{P}\bar{X}(U) < 1$, the method of iterations was used to calculate β. First approximations were found by approximating the ratio of the left parts of eqs. (3) and (6) to the linear function $B(1+\beta_0 X)$ for $n = 0$ (B is a constant).

Table

$P_\perp$ interval (GeV/c)	Average value of $P_\perp$ in the int.	Polarization of Λ°	χ^2 per 18 degrees of freedom
0÷0.2	0.131	+0.002±0.032	22.3
0.2÷0.4	0.305	−0.137±0.022	20.5
0.4÷0.6	0.492	−0.199±0.025	22.1
0.6÷0.8	0.683	−0.296±0.035	19.4
0.8÷1.0	0.881	−0.303±0.062	18.5
>1	1.150	−0.189±0.125	10.6

Subsequent approximations were found by approximating

$$N_E(X) \Big/ \sum_{n=0}^{3}(-\beta_j)^n N_n(X) \qquad (7)$$

to the linear function $B(1+\beta_j X)$, where j is the number of iteration. In practice, it was enough to find the second approximations, i.e., one could limit oneself to the calculation of β_1.

The justice of this procedure was checked by simulations of Λ° with the known β meanings.

Figure 4 presents the distributions

$$\Phi_1(X) = F(X) = \sum_{n=0}^{3}(-\beta_1)^n N_n(X)$$

for different $P_\perp$ intervals.

The analysis of $K^\circ_s \to \pi^+\pi^-$ events detected in this experiment has shown that the asymmetry of K°_s decays agrees with a zero value ($\mathcal{P}(K^\circ_s) = 0.011\pm0.028$ for the P intervals from 0 to 1.2 GeV/c). The analysis of K°_s events is made similar to that of Λ°.

The results of measuring the polarization of Λ° versus $P_\perp$ are presented in the Table and fig.5. The errors in the polarization values are given taking the procedure of their calculation into account. These data show that the P dependence of the polarization of Λ°, produced in inclusive processes by 40 GeV neutrons and by protons /1-8/, is the same. These experimental data do not contradict the theoretical predictions /10/ about a weak dependence of Λ° polarization on the type of beam particles at high energy and large $P_\perp$.

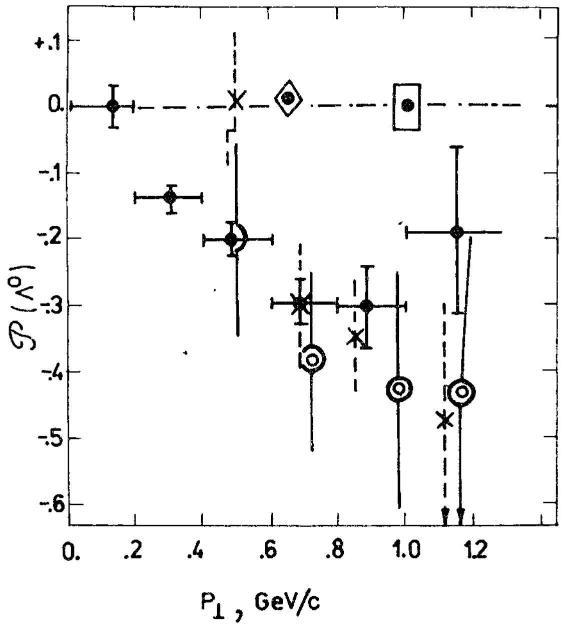


Fig.5. Λ° polarization versus $P_\perp$. Data of this paper: ♦ - polarization, ◈ , ▣ - average values of K°_s asymmetry relative to the production plane and of Λ° relative to their momentum vector in the lab. system, respectively. × , ◎ - data from paper [5] (pp for $\sqrt{s}$ = 53 GeV and 62 GeV).

Our data are described by the relation [21]

$$\mathcal{P} = -2m P_\perp \sin\Phi\, [\, 4m^2(1+\cos\Phi) + P_\perp^2]$$

for $m = 1$ GeV/c^2 and $\Phi = (1.41 \pm 0.08)$ rad.

Figure 5 also shows the average value of the lomgitudinal asymmetry of Λ° relative to their momentum vector in the laboratory system obtained in this experiment in the $P_\perp$ interval from 0 to 1.2 GeV/c.

This asymmetry agrees with zero value, as it follows from the parity conservation law in strong interactions, and equals 0.003 ± 0.033.

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Алеев А.Н. и др. E1-82-760
Поляризация Λ°, рожденных нейтронами
с энергией около 40 ГэВ на ядрах углерода

С помощью спектрометра БИС-2 ОИЯИ измерена поляризация Λ°, рожденных в инклюзивных процессах нейтронами с энергией около 40 ГэВ на ядрах углерода. Наблюдена поляризация Λ°, растущая с ростом поперечного импульса и согласующаяся с результатами измерения поляризации Λ°, рожденных протонами.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1982

Aleev A.N. et al. E1-82-760
Polarization of Λ° Produced by Neutrons
with an Energy of $\sim$40 GeV on Carbon Nuclei

The polarization of Λ° inclusively produced by neutrons on carbon at an average neutron energy of $\sim$40 GeV has been measured over the range of transverse momenta from 0 to 1.2 GeV/c. The Λ° polarization increases with increasing $P_\perp$ achieving 30% for about 0.8 GeV/c. The experiment has been performed using the BIS-2 spectrometer at the Serpukhov accelerator.

The investigation has been performed at the Laboratory of High Energies, JINR.

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